



# RCA INSTITUTES

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## Technical Lesson 28

### PRACTICAL RADIO CONSTRUCTION

The Simple Regeneration Receiver. The purpose of this lesson is to teach the constructional details and underlying theory of the simplest practical type of vacuum tube receiver - the regenerative detector - and to demonstrate in actual practice the value of regeneration in securing sensitivity and selectivity. There are two or three general types of receivers still simpler, but they are obsolete and impractical; so much so as to render them useless under present day radio conditions. So we shall begin with the regenerative vacuum tube detector - a receiver which is easy to build and simple to operate, yet is both sensitive and selective.

As stated in the previous paragraph the purpose of this lesson is to teach constructional details and underlying theory. If the student has the radio parts on hand to accomplish the actual step-by-step assembly of the receiver he should use them; on the other hand if the parts are not readily available the principles will nevertheless be mastered. This lesson, and lessons 29, 30, 31, 34, 36, 48, and 52 teach the underlying theory of tuned and untuned radio frequency receivers, balanced and neutralized receivers and audio and radio frequency amplifiers in general. Lessons 32 and 33 teach the practical constructional details and theory of screen-grid receivers. A complete kit of modern apparatus is furnished with lessons 32 and 33 to enable the student to accomplish all the practical work required.

There are a variety of ways in which regeneration may be secured and controlled, and this lesson will serve to familiarize the student with one of the best known methods of securing and controlling regeneration in a vacuum tube detector. It will also serve to demonstrate, in practical fashion, the valuable advantages to be derived by the proper utilization of regeneration.

Before entering into the constructional details of the receiver, however, it may be well to outline briefly the functioning of the various instruments as the signal traverses the circuit from the antenna to the headphones. Consider first the antenna circuit. Here we have an elevated wire, the antenna, and a connection to ground, there being in series with this antenna-ground system a coil composed of but a few turns of wire.

The foregoing arrangement constitutes an oscillatory circuit composed principally of the concentrated inductance of the coil shunted by the distributed capacity of the antenna and, being such, is capable of responding to electrical impulses of an oscillatory nature. Thus, it can readily be appreciated that when the elevated antenna wire intercepts the electromagnetic waves being radiated from a distant transmitter, an oscillatory current will be induced in the receiving antenna circuit because, under such conditions, we have electrical impulses of an oscillatory nature acting upon an oscillatory circuit.

The Oscillatory Circuit. The usual oscillatory circuit, composed of a concentrated inductance in the form of a coil and a concentrated capacity in the form of a condenser, shown in Figure 1, must be tuned by adjustment of the values of inductance or capacity, or both, to the frequency of the particular current being dealt with. Because the resistance of such a circuit is usually of a reasonably low value, such a circuit will resonate sharply to the specified frequency. Figure 1A illustrates the response curve of such a sharply resonant circuit tuned, for instance, to a wavelength of 400 meters.

If resistance is added to such a circuit, as shown in Figure 2, it will tune less sharply and, as the amount of resistance is increased, it will tune more and more broadly. This will result in the circuit responding over a wide band of wavelengths, as depicted in Figure 2A, rather than to a narrow band of wavelengths as in Figure 1A.

Tuning the Antenna System. With the foregoing in mind you should observe that no provision has been made for tuning the antenna circuit. Due to the fact that the capacity of this circuit is of a distributed character, and that the antenna system is a device of inherently high resistance, this circuit, rather than tuning sharply, is broad in its tuning. When the dimensions of the antenna are suited to the wavelength range to be covered by the receiver, the antenna circuit will be sufficiently non-critical in its tuning to respond to all wavelengths within that range with practically equal facility. Such an antenna system is known as an aperiodic, or untuned antenna.

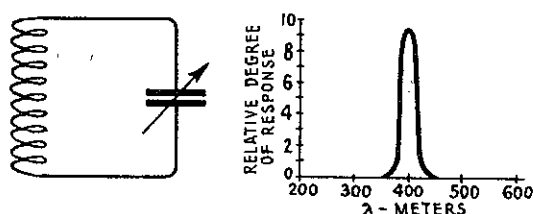


Figure 1.

Figure 1A.

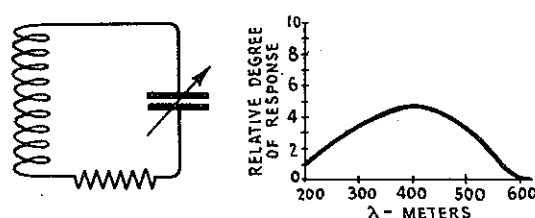


Figure 2.

Figure 2A.

It should be borne in mind that some advantage is to be gained in the way of sensitivity and selectivity by tuning the antenna - and, furthermore, that such tuning adds at least one more control to the receiver. The form of untuned antenna shown here, or a modification thereof, is used in the great majority of broadcast receivers inasmuch as it eliminates a tuning control and the loss in sensitivity and selectivity is not pronounced. In other words, it is the consensus of opinion that such loss is more than compensated by the reduction of the number of tuning controls with the consequent increased ease of tuning in the hands of the inexperienced user. It will be seen, then, that this antenna coil is not a tuning inductance, but solely a coupling coil insofar as it serves to couple the antenna circuit to the grid (secondary) circuit of the tuner.

When electro-magnetic waves radiated by distant transmitters pass the receiving antenna they induce therein radio-frequency currents. Due to the non-selective characteristics of this type of antenna circuit, as outlined above, it is entirely possible that the signals from a dozen or more transmitters



the antenna circuit, a transfer of energy will take place. A current of corresponding frequency will then flow in circuit LC and voltages will be developed across the circuit terminals XY. These terminals are connected to the input terminals of the vacuum tube, i.e., its grid and filament terminals, thus impressing these high frequency potentials upon the grid of the tube and causing corresponding fluctuations of the grid voltage. These radio-frequency variations of the grid voltage cause corresponding fluctuations of the plate current, these fluctuations being of the same frequency and possessing the same characteristics as those of the wave which is acting upon the antenna.

Operation of Detector Tube. By virtue of proper values of plate voltage and grid bias voltage the tube is being operated on the lower knee of its characteristic curve, the point best suited to detector action. Due to the phenomenon of detection not only is there a radio frequency current present in the plate circuit of the tube, but there is also present a low frequency current, this low frequency current being an exact reproduction of the modulation of the radio wave.

When speaking of operating a tube on the lower knee of its characteristic curve it should be borne in mind that all tubes of the UX-199, UX-201A, UX-112 and UX-112A types are adjusted for detector operation by applying 45 volts plate potential, using a grid condenser of .00025 mfd. in conjunction with a grid leak of 2 to 9 megohms (grid leak resistance is not critical in value) and a grid return to the positive terminal of the filament. The "grid return" is the connection denoted as YZ in the schematic wiring diagram, Figure 3.

Such a grid return, in conjunction with the proper value of grid leak, serves to keep the grid at the correct value of negative biasing potential necessary to good detector action. Should the grid return be made to the negative side of the filament, the grid biasing potential would be upset with consequent reduction in the efficiency of the tube as a detector.

When using the super-sensitive detector tube UX-200A, the grid return preferably should be made to negative filament, but bringing the grid return to positive filament does not seriously effect its excellence as a detector.

Action of the Detector Tube. In a previous lesson it has been pointed out that at the broadcasting station audio frequencies are superimposed upon the radio wave and that this superimposition is termed "modulation". The radio wave serves only to carry these audio-frequencies to distant receivers and thereby derives the term "carrier wave". Before currents of such frequency can be utilized to operate headphones or loudspeakers (devices which convert the audio-frequency currents to sound waves) it is necessary to separate the radio-frequency from the audio-frequency. This, in brief, is what the detector tube accomplishes - it separates the audio-frequency from the radio-frequency and, at the same time, amplifies the received signal.

Although the plate current of the tube is direct current, the alternating voltages actuating the grid of the tube do, in effect, superimpose an alternating current upon the plate current. Thus, the plate current of the tube may be, and is, considered as possessing an alternating current component.

This is true when the tube is operating as an amplifier but, when the tube is being operated as a detector, two alternating current components are simultaneously present in the plate circuit, one being of radio-frequency and the other of audio-frequency.

These two alternating current components flowing in the plate circuit encounter divided, or parallel, paths at point D. One path lies through the headphones and B battery to filament; the other through the condenser  $C_b$  to filament. The alternating current components of the plate current will, of course, take that path which offers the least opposition to their flow and, in the case of condenser  $C_b$ , such opposition will take the form of capacitive reactance.

On the other hand, the opposition to the flow of alternating current through the headphones will be principally in the form of inductive reactance, for the magnet winding of the headphones is composed of a great many turns of very fine wire wound upon a steel core. Such winding possesses a high value of inductance - a value which may easily be of the order of several henries. Assuming that the inductance of the headphone winding is, say, three henries we can readily determine its inductive reactance to alternating currents of any specified frequency.

If the length of the received wave is, for example, 300 meters, the frequency of the oscillatory current induced in the antenna and transferred to the receiver will be 1,000,000 cycles per second, and the radio-frequency AC component of the plate current will be of corresponding frequency. Also, due to the phenomenon of detection, we have present in the plate circuit a low-frequency AC component corresponding to the audio-frequency modulation of the radio wave, and this will average, let us say, 1,000 cycles per second. Applying these known values to the formula for inductive reactance ( $X = 6.28fL$ ) and to the formula for capacitive reactance  $X_c = \frac{1}{6.28fC}$  we can readily

determine the reactance of each path for each of the two frequencies involved. In this manner we find that at a frequency of 1,000 cycles per second the inductive reactance of the headphones is 18,840 ohms. At the same frequency the capacitive reactance of the condenser, which has a capacity of .001 mfd. is 159,235 ohms. Needless to say, the audio-frequency component will flow through the headphones rather than through the condenser.

By the use of the same formulas we can now determine the inductive and capacitive reactances of the headphones and condenser, respectively, at a frequency of 1,000,000 cycles. At this frequency the inductive reactance of the headphones is 18,840,000 ohms, while the capacitive reactance of the condenser is but 159 ohms. Thus it is apparent that the radio-frequency component of the plate current will flow directly to the filament circuit through condenser  $C_b$ . This condenser, then, serves to pass the radio-frequency component around the high inductive reactance of the headphones, and from this it derives its name "by-pass" condenser.

In this fashion the radio-frequency, having brought to us the audio-frequency currents originating in the studio of the broadcasting station and enabled us to secure regeneration - upon which we shall dwell at greater length later - has served its useful purpose and is then provided with a direct path to filament. On the other hand, the audio-frequency component is forced to flow

through the headphones which is fully in accord with purpose of the device. The headphones are for the purpose of converting these audio-frequency currents to sound waves, thereby making them audible to the human ear.

Theory of Regeneration. Having briefly outlined and reviewed the more simple phenomena encountered in the passage of the signal from antenna to headphones let us now turn our attention to that phenomenon which is termed "regeneration." Regeneration has, on occasion, been referred to as the simplest and most economical known method of radio-frequency amplification and - such it really is for it effects a marked degree of amplification of the received signal at radio frequency. Its use results in greatly improving the sensitivity and selectivity of the receiver, or in other words it increases the volume of nearby and semi-distant stations and makes possible the reception of distant stations to which the tube would not otherwise give audible response. At the same time, regeneration increases the ability of the receiver to completely tune out undesired signals from stations operating on wavelengths closely adjacent to that of the desired signal.

Regeneration is best defined as being the feeding-back of radio-frequency energy from the plate (output) circuit to the grid (input) circuit in such fashion that the fed back energy strengthens, or reinforces, the signal energy actuating the grid of the tube.

When the voltage of an incoming signal is impressed upon the grid of the tube, it causes a variation of the grid voltage. It should be borne in mind that any variation of the grid voltage, no matter how slight such variation may be, results in a comparatively great fluctuation of the plate current. This, in brief, is what constitutes amplification inasmuch as a small amount of energy introduced into the input (grid) circuit releases a comparatively large amount of energy in the output (plate) circuit. (Incidentally, it is this ability of a vacuum tube to amplify that makes regeneration possible.) Furthermore, any increase in the amplitude of the signal voltage will result in an increase in the fluctuations of the plate current. This, in turn, will mean a more vigorous vibration of the headphones diaphragm, i.e., louder signals.

It is entirely practicable to take some of this amplified energy from the plate circuit and return a portion of it to the grid circuit. Properly done, this returned or fed back energy increases the amplitude of the signal voltage actuating the grid, and such a procedure is termed "regeneration".

The Regeneration Circuit. In the receiver being dealt with in this lesson, a diagram of which is shown in Figure 3, regeneration is secured by means of the coil T. A glance at the schematic diagram, Figure 3, will show that this coil termed the "tickler" coil, is in series with the plate circuit and, furthermore, that it is inductively coupled to the grid coil L. Obviously any current flowing in the plate circuit must, of necessity, traverse the tickler coil and thus set up about this coil a magnetic field. As the tickler coil is coupled to the grid coil L, a number of the turns of the grid coil will lie within the magnetic field of the tickler coil. Here, then, we have fulfilled two of the primary requisites necessary for the transfer of energy from one circuit to another by virtue of electro-magnetic induction. However, as long as the plate current is of constant strength, the magnetic field of the tickler coil does not vary, and consequently no induction between tickler and grid coil occurs.

When an incoming signal impresses its varying voltage upon the grid, corresponding fluctuations of the current take place immediately in the plate circuit, which in turn cause similar changes in the magnetic field of the tickler coil. As soon as this magnetic field of the tickler coil changes, the grid coil is thereby subjected to a varying magnetic field, or in other words the grid coil is being "cut" by moving magnetic lines of force, and induction results. In this manner some of the amplified energy released in the plate circuit by variations of grid potential is returned to the grid circuit.

The voltage induced in the grid coil by this feed-back combines with the signal voltage so that the total voltage actuating the grid of the tube is the resultant of this combining of the signal and feed-back voltages. When, at any given instant, the feed-back voltage is of the same polarity as the signal voltage, the combining of these two voltages will be additive. Thus, the initial voltages actuating the grid are intensified, resulting in still greater fluctuations of the plate current with consequent increased signal strength.

On the other hand, if the magnetic field of the tickler coil be reversed so that the feed-back voltage is, at any given instant, of opposite polarity to that of the incoming signal, the feed-back voltage will, naturally, oppose the signal voltage. Such a condition as this will result in a reduction of the voltage acting upon the grid with consequent decreased signal strength and, should such feed-back be present to any appreciable degree, it will render the receiver wholly inoperative.

Limitations of Regeneration. From the foregoing it can readily be seen that care must be exercised to insure the feed-back voltage being of such polarity that it strengthens the initial signal voltage - for only under such conditions can regeneration be secured. Regeneration, however, can be carried too far for broadcast reception purposes because, when feed-back is increased beyond a certain point, the tube becomes a self-excited oscillator, i.e., it becomes a generator of radio-frequency oscillations.

This condition is highly undesirable in broadcast reception for, when the tube is oscillating, a reaction takes place between the incoming signal oscillations and the oscillations being generated by the tube, which results in a whistling squeal that drowns out the voice and music. This reaction is technically designated as "autodyning" and the resultant squeal is termed the autodyne, or "beat" frequency.

Control of Regeneration. It is necessary to provide some means by which the feed-back can be controlled so that just the right amount of regeneration may be secured and, furthermore, this control must be easily and quickly variable. This provision for the control of regeneration is necessary in view of the following facts. (a) The tube is most sensitive when the amount of feed-back is kept just below that value of which the tube begins to oscillate. This is known as the point of maximum regeneration. (b) This point of maximum regeneration is different for each wavelength to which the grid circuit is tuned. Control of regeneration may be secured in a variety of ways and, in the circuit under consideration, this is accomplished by varying the coupling between the tickler and grid coils. This variation of the coupling between these two coils could be secured by varying the distance



between them, but the method actually employed in this receiver is a more convenient one. Here the tickler coil is so mounted that it can be rotated thus providing a means of varying the angular displacement of the tickler coil with respect to the grid coil. If you have really learned the fundamentals of electro-magnetic induction and the considerations which enter into its application and control, as set forth in the lesson covering that subject, you will readily appreciate that when the tickler coil is set at right angles to the grid coil, minimum coupling is secured with consequent minimum feed-back. Therefore, when these two coils are at right angles to each other, regeneration is practically non-existent. When the tickler is parallel to the grid coil, the maximum available coupling is obtained and, of course, feed-back is greatest. Thus, varying the angular displacement of these two coils from right angles to parallel affords a continuously variable control of regeneration.

When the grid circuit is tuned to any specific wavelength, for instance 300 meters, it will be found that when the tickler coupling is increased to a certain value the tube will begin to oscillate. This point at which the tube goes into oscillation is indicated by a more or less distinct "plop" followed by a rather faint hissing sound in the headphones - not loud but unmistakable. As previously indicated, when the tube oscillates, satisfactory reception of broadcasting is quite impossible because of the autodyne "squeal". Reducing feed-back by loosening the tickler coupling will bring the tube out of oscillation, i.e., cause it to stop oscillating. This adjustment of feed-back at which the tube is just on the verge of breaking into oscillation is the point of maximum regeneration where signal strength is greatest and tuning is sharpest.

Decreasing feed-back below the amount necessary for maximum regeneration results in a pronounced decrease in sensitivity and selectivity. On the other hand, regeneration should not be forced too far, for it will then result in distortion, that is, the received voice and music will sound unnatural and be of poor quality. The adjustment of feed-back at which maximum signal strength is secured without distortion might well be termed the point of optimum regeneration. The point at which one secures maximum regeneration is critical of adjustment and varies with each change of tuning, i.e., whenever the variable condenser controlling the tuning of the grid circuit is varied, the tickler coupling must also be varied in order to keep the tube in its most sensitive condition - just below the point at which it goes into oscillation.

The lower the wavelength to which the grid circuit is tuned, the more readily does the tube oscillate; in other words, the lower the wavelength of the grid circuit, the less will be the amount of tickler coupling needed to secure optimum regeneration. Conversely, the higher the wavelength to which the grid circuit is resonated, the greater will be the amount of tickler coupling necessary for optimum regeneration.

In practical operation it will be found that if the grid circuit is tuned, for example, to a wavelength of 300 meters, a certain amount of tickler coupling will be necessary to secure the greatest amount of regeneration possible without introducing distortion or oscillation. Then if the wavelength of the grid circuit is raised to, let us say, 370 meters, the tube will suffer a pronounced decrease in sensitivity, for the value of tickler coupling sufficient for maximum results at 360 meters will prove insufficient for optimum



regeneration at the higher wavelength of 370 meters. To secure best results it will be necessary to increase tickler coupling to again obtain the critical value of optimum regeneration.

On the other hand, if the wavelength of the grid circuit is lowered from 360 meters, to for instance, 350 meters, the tube will promptly begin to oscillate because the amount of feed-back that gives optimum regeneration at 360 meters will prove excessive at any lower wavelength such as 350 meters. Therefore, as this oscillation is the inevitable result of feed-back in excess of that required for optimum regeneration, a reduction of the tickler coupling will be necessary to cause the tube to stop oscillating. If the feed-back is in this way decreased until the tube just ceases to oscillate, maximum regeneration is again secured.

Summary of Operation. In view of the foregoing considerations, it is apparent that a continuously variable control of feed-back is necessary to the operation of this circuit, and such control is secured in this receiver by employing a rotating tickler coil.

As might be expected, although regeneration, when properly controlled, is a valuable asset to the operation of the vacuum tube detector, it is not without its drawbacks. The principal drawback encountered in the utilization of a rotating tickler coil as the means of securing and controlling regeneration is that moving the tickler influences the tuning of the grid circuit. This is readily apparent in view of the following considerations. The tickler must, of necessity, be located within the magnetic field of the grid coil. This results in distorting the grid coil's magnetic field, and such distortion is further intensified by the fact that the tickler possesses a magnetic field of its own and the inevitable reaction that takes place between these two inter-linking fields. The result of this distortion of the grid coil's magnetic field is to change the effective inductance of the grid coil.

If the grid circuit is to be kept tuned to a specific wavelength, it is necessary to compensate for this change in the effective inductance of the grid coil by a change in the tuning capacity associated therewith. This change in the effective inductance of the grid coil varies with each movement of the tickler coil and, in practical operation of the receiver, it will be found that when the tickler coil is rotated, be it ever so slightly, the tuning condenser must be readjusted in order to maintain the circuit at resonance with the desired signal.

A brief summary of the advantages and disadvantages of regeneration follows:-

Advantages: (a) It increases the sensitivity of the receiver.

(b) It increases the selectivity of the receiver.

Disadvantages: (a) Its adjustment for maximum results is a variant with wavelength. (That is, it cannot be "set" and thereafter be "let alone".)

(b) Adjustment of the regeneration control exerts a de-tuning effect upon the grid circuit.

Constructional Details of a Simple Regeneration Circuit. With the foregoing instruction in mind, let us now turn our attention to the constructional details of a radio receiver incorporating regeneration controlled by a rotating tickler coil. Read the instructions thoroughly and endeavor to learn each instrument by its name.

The instruments used in the construction of this circuit are:

- |                           |                                  |
|---------------------------|----------------------------------|
| 1 - panel                 | 1 - grid condenser (.00025 mfd)  |
| 1 - baseboard             | 1 - grid leak (2 megohms)        |
| 1 - "three circuit tuner" | 1 - by-pass condenser (.001 mfd) |
| 1 - variable condenser    | 2 - tip jacks                    |
| 1 - vacuum tube socket    | 1 - terminal strip               |
| 1 - pair headphones       | 1 - 4-inch dial                  |
| 1 - rheostat              | 1 - 3-inch dial                  |

If the student has the parts just listed he may follow this instruction. The real purpose of these lessons is to teach you, in a practical manner, the underlying theory and practice of the various fundamental circuits which form the ground work for the more advanced instruction that you will receive later.

A complete kit of parts is supplied to each student for his work on electrically operated screen-grid receivers, the constructional details of which are taught beginning with Lesson 32. However, too much time and thought cannot be given to these lessons that precede the screen-grid instruction, as well as those that follow the screen-grid subject. Do not lose sight of this advice.

**The panel is drilled with the holes necessary to attach such apparatus as will be mounted upon it.**

The first step in the building of the receiver is to fasten the panel to a baseboard. This baseboard may be any ordinary piece of wood one-half inch thick and eight or nine inches in width. It is the usual practice to make the baseboard an inch shorter than the panel. Along the bottom edge of the panel are four holes through which four wood screws are passed and screwed into the edge of the baseboard. Attach in such manner that the panel projects one-half inch beyond the baseboard at each end.

Mounting the Instruments. The instruments to be mounted upon the panel are a variable condenser, the three-circuit tuner, the rheostat and the two tip jacks. These instruments are attached to the panel, as shown in the accompanying "picture" diagram, Figure 4, by means of the panel holes provided for this purpose.

Other instruments are screwed to the baseboard and, in this receiver, these are the terminal strip and the vacuum tube socket, their proper positions being clearly shown in the diagram. Note the placement of the tube socket as regards its terminals, i.e., the grid (G) and plate (P) terminals toward the rear of the baseboard and the two filament terminals (marked + and -) toward the front of the baseboard. With all the instruments mounted in their proper positions upon the panel and baseboard, we are now ready to begin wiring.

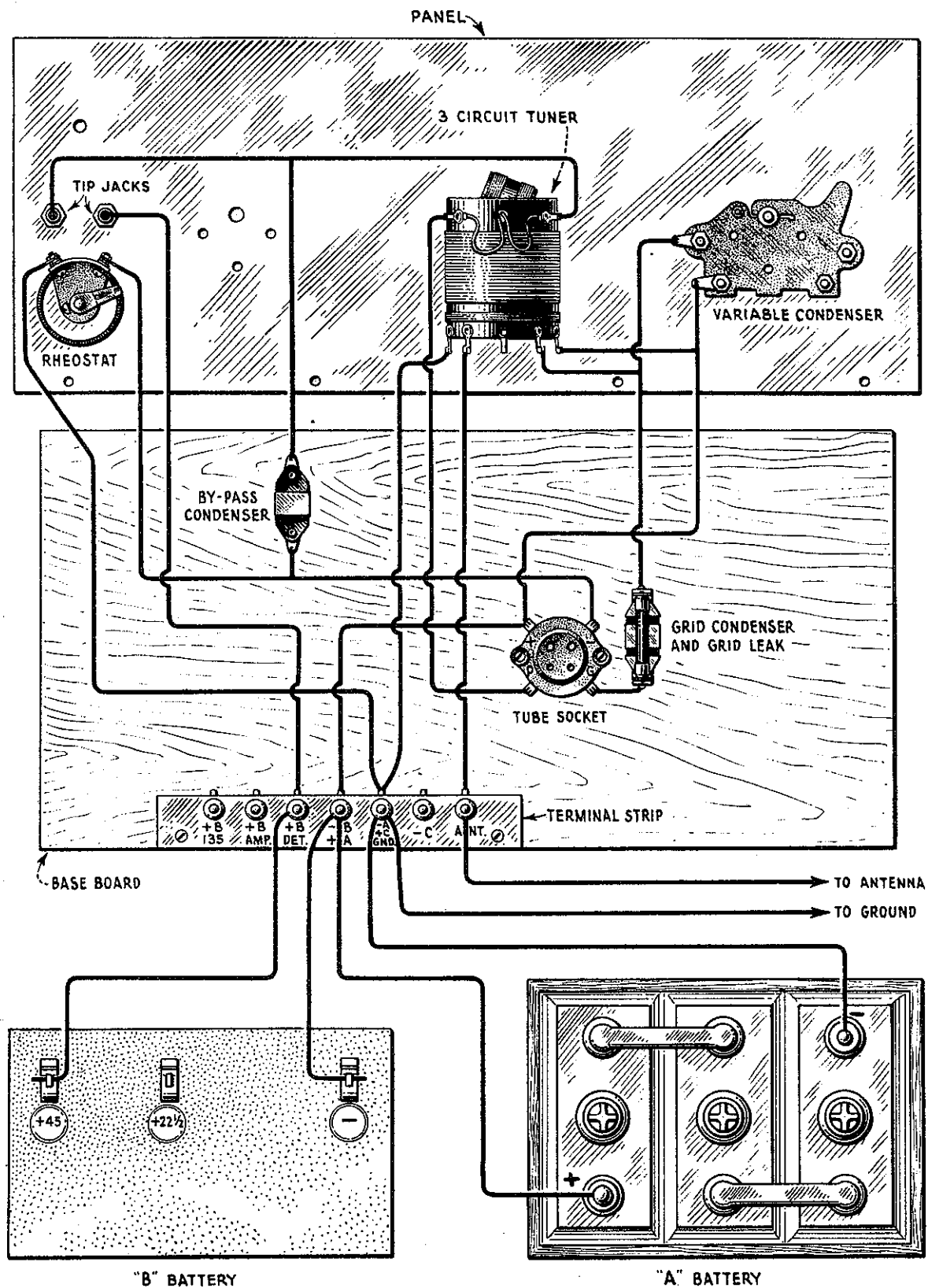


Figure 4.

In wiring any radio receiver it is usually the best practice to wire in the filament circuit first. This is done by connecting a wire to the negative A (-A) binding post on the terminal strip, the other end of the wire being connected to one of the terminals of the rheostat. A wire is now connected to the remaining terminals of the rheostat and thence to the negative filament terminal socket. The positive terminal of the tube socket is then connected to the positive A (+A) binding post of the terminal strip.

The tube sockets furnished with this kit, like many of the sockets being marketed, have their filament terminals indicated by polarity signs (+ and -). Actually, such polarity signs mean little except to indicate the filament terminals of the socket because, as far as the practical operation of the tube itself is concerned, the relative polarity of the filament terminals is of no consequence. However, in connecting the tube to the various circuits with which it is required to function, it does make a difference to which side (positive or negative) of the filament circuit such connections are made. If the student carefully observes these polarity markings and is governed thereby when wiring in the filament circuit, he will be able subsequently to determine quickly and easily the polarity of the filament wiring without it being necessary to trace such wiring back to the filament battery. However, when working upon receivers built by others, no dependence should be placed upon such socket filament markings, for more often than not such polarity marks have been haphazardly disregarded and, therefore, will prove misleading.

Connecting the Instruments. The three-circuit tuner comprises three coils, one rotating and two stationary. The rotating coil is the tickler coil and, of the two stationary coils, the smaller is the primary (antenna) coil, while the larger is the secondary (grid) coil. The terminal wires of these coils are soldered to lug terminals securely fastened to the coil form to facilitate the connecting of the coils in circuit. To just what terminals the ends of each coil are connected can easily be determined by examination, as these connections are plain and easily traceable.

The antenna coil is placed in circuit by connecting one of its terminals to the antenna (ANT) binding post and its other terminal to the ground (GND) binding post on the terminal strip.

Connection to the secondary coil (the larger of the two stationary coils) is affected by means of lugs to which the ends of the coil are soldered. Before preceeding with the connections to this coil, note carefully the lug to which is connected that end of the secondary coil farthest from the antenna coil, and also the lug which is connected to that end of the secondary coil nearest the antenna coil. Having done this, turn your attention to the variable tuning condenser.

The variable tuning condenser consists of two interleaved sets of plates - one group of plates being stationary (stator plates), the other group being movable (rotor plates). It is equipped with two terminals, one of which is attached directly to the metal end plate of the condenser, thereby providing a means of connection to the frame and rotor plates. The other terminal is mounted upon an insulating bushing and affords a means of connection to the stator plates.

A wire is now connected to the rotor plates of the condenser, by means of the terminal provided for this purpose, and the other end of this wire is connected to the lug on the three-circuit tuner which connects to the end of the secondary coil nearest to the antenna coil. From the same connection another wire is now run to the positive side of the filament, i.e., to the wire which connects the "A" binding post on the terminal strip to the corresponding filament terminal of the tube socket. The stator plates of the condenser are now connected to the coil terminal which, in turn, connects to that end of the secondary coil furthest from the antenna coil. In this manner the rotor plates of the condenser are connected to the "low" end of the secondary coil and thence to the positive side of the filament circuit, while the stator plates of the condenser are connected to "high" end of the secondary coil. Care should be exercised that these connections be made as specified.

The grid condenser is the small fixed condenser equipped with the clips, in which the 2-megohm grid leak is inserted, and marked as having a capacity of .00025 mfd. One terminal of this condenser is connected to the grid (G) terminal of the tube socket. This can be done by soldering the lug terminal of the condenser directly to the socket terminals, or a short piece of stiff wire may be used to connect these two terminals. The remaining terminal of the grid condenser is connected to the wire running from the stator plates of the condenser to the "high" end of the secondary. If the grid condenser is soldered directly to the proper socket terminal, or if the connections to the condenser are made of fairly stiff wire, no additional means of mechanical support will be necessary in a temporary hook-up such as this.

The grid leak should be removed from its clips on the grid condenser when soldering connections to this condenser, in order to avoid possible injury to the resistance element of the grid leak due to the heat of the soldering iron. Replace the grid leak when soldering has been completed and the terminals of the condenser have cooled.

One of the tickler coil terminals is now connected to the plate (P) terminal of the tube socket, while the other terminal of this coil is connected to a tip jack. The other tip jack is connected to the "B + Det" binding post on the terminal strip.

The by-pass condenser is a small fixed condenser having a capacity of .001 mfd. One terminal of this condenser is connected to that tip jack which is connected to the tickler coil. The other terminal of this condenser is then connected to the negative side of the filament circuit. This completes the wiring of the receiver.

Mounting the Dials. A four-inch dial is now attached to the shaft of the variable condenser by means of the set-screw provided for this purpose. Before the dial is fastened in place, however, an indicating marker should be placed upon the panel. This marker may be a line scratched upon the surface of the panel by means of some sharp-pointed instrument, such as a pen-knife, or it may be drawn in ink on a bit of paper above the shaft of the variable condenser and so positioned that it lies at the edge of the dial. When properly mounted, the 100 division on the dial will be opposite the indicating marker on the panel when the condenser is set at its maximum value of capacity, i.e., rotor plates completely interleaved with the stator plates, and the zero division on the dial will be opposite the indicating marker when the condenser is set at minimum capacity.

A similar indicating marker is provided for the three-inch dial which is attached to the shaft of the tickler coil. When properly placed, the zero division on the dial will be opposite the indicating marker when the tickler coil is at right angles to the secondary coil, and the 90 dial division will be opposite the marker when these two coils are parallel.

Check all connections. Before connecting the batteries and placing the tube in its socket, it would be well to check and then re-check each and every connection in the receiver to make certain that they are correct. As a final precaution, test the circuit for possible incorrect connections and short circuits which will impress the "B" battery voltage upon the filament circuit. Should such a condition exist, the filament of the tube will be burned out as soon as the battery voltages are applied.

Such a test is best made in the following manner: Connect all batteries to the receiver, but do not place the tube in its socket. Turn the filament rheostat on and then connect a D. C. voltmeter to the filament terminals of the tube socket. This voltmeter should be one that reads from 0 to 50 volts or from 0 to 100 volts. The voltmeter should read no more than the voltage of the "A" battery, i.e., 4.5 volts or 6 volts as the case may be. Should the voltmeter read 45 volts (the voltage of the "B" battery) it is a sure indication that, through a mistaken connection, the "B" battery voltage is across the filament circuit. Such a circumstance would surely result in the tube filament being burned out were the tube to be inserted in the socket. Check the plate circuit wiring until the mistaken connection is found.

If a voltmeter suitable to the aforementioned test is not available, the test may be made as follows:- Connect only the "A" battery to its proper binding posts - do not connect the "B" battery to the receiver in any way. Place the tube in its socket and turn on the rheostat until the tube is lighted. Leaving the rheostat set at this position, shift the positive "A" battery lead to the positive "B" battery binding post. Now connect the negative "A" battery lead, first to the positive, then to the negative, "A" battery binding posts. The tube should not light. If it does light when the negative "A" battery lead is connected to either the positive or negative "A" battery binding post, it indicates that the "B" battery circuit is short-circuited to the filament circuit. If the tube has not lighted then it is safe to connect both the "A" and "B" batteries to their respective posts, taking care to observe the correct polarities, i.e., negative "A" battery to -A binding post, positive "A" battery to +A binding post, negative "B" battery to -B binding post, and positive "B" battery to that binding post marked +B Det.

Of the four prongs on the base of the tube, the two filament prongs are of larger diameter than the grid and plate prongs. The openings in the tube socket in which these prongs are inserted are of corresponding diameters, and care should be exercised that the tube is properly inserted as regards its prongs. The proper insertion of the tube is further facilitated by the small brass pin on the side of the tube base. When the tube is properly inserted, this small pin should point in the same direction as the small arrow engraved on the top of the socket.

Connect the antenna and ground to their respective binding posts and insert the tips of the phone cord in the two tip jacks on the panel. The receiver is now ready for operation.

Tuning the Receiver. The manner in which the controls of this receiver are manipulated in order to tune in the signals from distant transmitters will prove to be a simple matter, if you have learned by careful study the facts contained in the foregoing instructions. Keep in mind the factors governing the production and control of regeneration, and the manner in which such factors vary with changes in tuning.

Begin tuning at the shorter wavelengths (about 200 meters) by setting the condenser at, or near, minimum capacity; then gradually increase the wavelength to which the receiver is tuned by slowly increasing the capacity of the tuning condenser. At the same time, keep the tube adjusted for maximum regeneration by proper manipulation of the tickler coil.

More specifically, set the condenser dial at about 10 and adjust the tickler coupling so that the tube oscillates. When the tube starts to oscillate, a more or less distinct "plop" followed by a rather faint hissing sound will be heard in the headphones. Should there be any doubt as to whether or not the tube is oscillating, a good test can be made in the following manner. Tap one of the grid condenser terminals with a moistened finger tip. If the tube is oscillating a distinct "cluck" will be heard in the headphones each time this terminal is tapped.

As soon as the tube oscillates, reduce the tickler coupling until the tube just stops oscillating, this being the adjustments for maximum regeneration.

Now increase the wavelength of the receiver by increasing the condenser capacity very gradually, meanwhile keeping the feed-back adjusted for maximum regeneration by an equally gradual increase in tickler coupling. In this manner the wavelength range of the receiver (200 to 550 meters) is covered until a station is tuned in. When a station is heard, carefully adjust the receiver to exact resonance with the incoming signals by means of the tuning condenser, and adjust the feed-back until maximum signal strength without distortion or oscillation is secured.

This is all the instruction that can be given on paper in regard to operating this receiver. The knack of tuning comes only with practice and so the student should not stint himself as to the amount of time he spends with this receiver in learning the rudiments of the tuning adjustments. It may be found that only a small amount of tickler coupling is required for maximum regeneration, even at the longer wavelengths in the vicinity of 500 meters. This makes the control of feed-back rather critical and is an indication of too many turns of wire on the tickler coil. Easier adjustment and control of regeneration could be secured if nearly maximum tickler coupling were necessary for regeneration at the longer wavelengths; and this could be secured by taking turns off the tickler coil.

This reduction of the number of turns on the tickler coil is not recommended, because the same coil is to be used in subsequent experiments in which the number of turns on it will be none too many. Therefore, it is not advisable that the student take off any turns as it will save him the trouble of replacing them in future experiments.

If the receiver, however, were to be a permanent one, then the proper procedure would be to reduce the number of turns on the tickler coil until nearly



maximum tickler coupling would be necessary for regeneration at 550 meters. It would then be found that only a small amount of tickler coupling would be necessary for regeneration at 200 meters. In this fashion greater ease of regeneration control would be secured, for the range of its adjustment would be spread over a greater portion of the tickler dial instead of being confined to a small portion wherein the control would prove critical of adjustment.

#### EXAMINATION - LESSON 28.

1. What is regeneration?
2. What simple test can be made to determine whether or not the tube is oscillating?
3. What is the purpose of the tickler coil?
4. How is the secondary circuit tuned?
5. What happens to the voice and music being received when the tube oscillates?
6. (a) What adjustment of feed-back gives greatest signal strength?  
(b) What adjustment of feed-back gives sharpest tuning?
7. Why is the tickler coil made movable?
8. In what manner does a variation in grid voltage effect plate current?
9. How may regeneration be controlled?
10. What may cause a tube to oscillate in a regenerative receiver?